Back to the future: restoring historical communities

By reconstructing the recent past of a damaged marine ecosystem, **Joan E. Cartes** and colleagues help envisage a future state to which protection and restoration can aspire.

All the Earth's ecosystems as we know them today have suffered the impact of human activities, and many of us will have wondered what they looked like before humans changed them. Some human activities have brought about local increases in biodiversity, for example, deployment of artificial reefs in marine habitats, but any alteration is likely to negatively impact larger-scale biodiversity patterns. Such changes in ecosystem succession can only be properly understood where we have knowledge of the historical loss of biodiversity. If, for each ecosystem, we could pinpoint a time in the recent past representing a 'pristine' reference, we should be able to 'reconstruct' a community free of significant human impacts. Such reconstructions will enable assessments of the current state of degradation of natural systems. Biological communities have also experienced historical changes through natural causes, so chronological reconstructions must always have natural variability in mind.

In a classic example of reconstruction of past communities, paleofloristic studies revealed that the regression of deciduous trees in the Iberian Peninsula was linked to human impact. In a warming world, logging of deciduous trees such as beech (*Fagus sylvatica*) in Mediterranean countries should be scrutinised since their exploitation is now accentuating the 'natural' poleward range contraction of such species in response to warming.

In marine environments, numerous studies have also reconstructed different communities over the last several thousand years using, for example, foraminiferans in sediments. But to what extent are 'recent' (century-scale) reconstructions possible in marine environments? In nearshore waters, the reconstructions carried out to date have evaluated changes in organisms such as fish which experience short timescale (decades or centuries) fluctuations in their populations. In the last century, north-eastern Atlantic waters experienced warming periods, for example from 1920–1930, leading to an increase in northern occurrences of warm-water species such as sardines and bluefin tuna, thus demonstrating that certain species can respond quickly to short-term environmental oscillations. When considering longer-term changes such as climate change, deep sea systems are optimal since they have high environmental stability compared to nearshore areas. This allows us to identify more subtle but progressive trends, for example the increase in salinity and warming taking place in the deep waters of the Mediterranean.

An important method for quantifying the density of past marine populations is to examine their remains buried in sediments. Historical variations in populations of pelagic fish such as sardines or anchovies have been analysed based on fluctuations in the number of scales deposited in sediment cores. Otoliths (calcified structures of the inner ear of fish) have been widely used because they are highly species-specific. In parallel, scientists can date sediment cores using radionuclides of lead and caesium with half-lives of several decades (^{210}Pb and ^{137}Cs with average half-life of 22 and 30 years, respectively). Once each level of the sediment column is dated, changes in species abundance can be related to climatic events or human impacts during the same period. This method is not without drawbacks, as sediment columns can be altered by geophysical processes after deposition.

The deep sea of the Balearic basin in the north-west Mediterranean is inhabited by the bamboo coral *Isidella elongata* (Fig. 1). Soft corals lend diversity to sedimentary, homogeneous, sea-floors, generating better conditions for recruitment and aggregation of other species. The

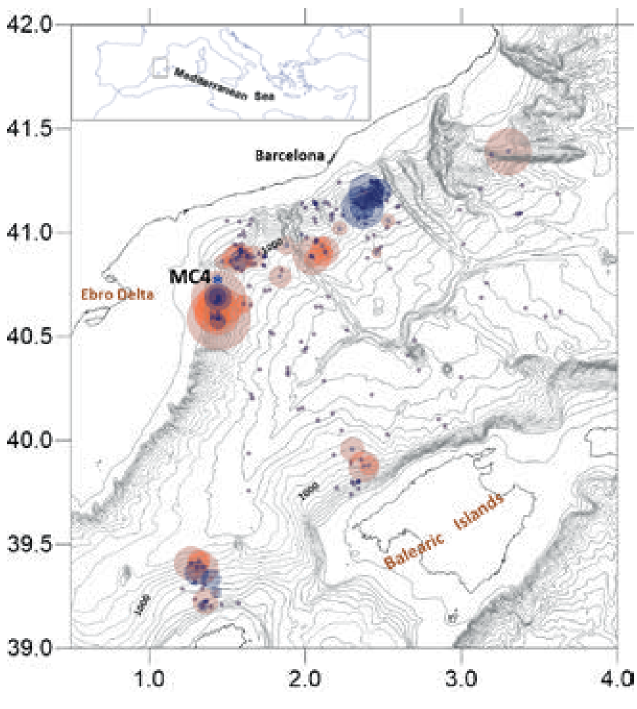


Figure 1. Study area in the Balearic Basin showing the current distribution (orange dots) and distribution prior to the start of trawling (dark-blue dots) of the bamboo coral *Isidella elongata* (own data). The 1000-m isobath represents the approximate limit of trawling fishing activity (each isobath is 100 m). Symbol size is proportional to coral biomass; the bathymetric lowest boundary of *I. elongata* is around 1300-1400 m. The Multicore MC4 station, at 398 m depth, off the Ebro Delta is indicated (*).

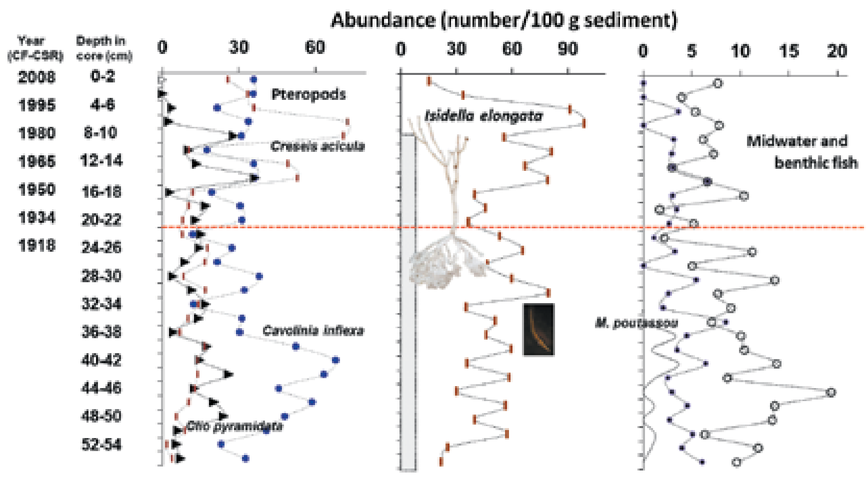


Figure 2. Standard ised abundances of the number of individuals per 100 g of sediment for indicatory taxa at the MC4 station in relation to sediment depth (in cm), with the estimated age of each level of sediments according to the CF-CSR model: i) pteropods (*Clio pyramidata*, *Cavolinia inflexa* and *Creseis acicula*), ii) *Isidella elongata* (sclerites, and occurrence of colony bases: grey bar), iii) midwater (mesopelagic) (o) and benthic (benthopelagic) fish.

colonies are highly vulnerable to removal by trawling, so it is important to identify where corals were distributed prior to trawling for future restoration of these communities.

In an attempt to reconstruct historical deep sea marine communities of the Balearic basin, we analysed a sediment core from 398 m depth off the Ebro Delta (location: sampling station MC4, see Fig. 1). We analysed the sediment core for bamboo coral sclerites and other faunal remains including fish otoliths, the shells of pteropods (representative of the zooplankton), and crab chelae (pincers).

We correlated faunal remains with radionuclide dating of the sediments which placed the 100 year horizon at 22 cm below the sediment surface. We estimated the rate of sediment accumulation based on the ^{210}Pb profile, and related the levels in the sediment column to their approximate age (see X axis in Fig. 2). The sediment accumulation rate here of 0.23 g cm^{-2}/yr was similar to that in comparable areas (e.g., Lacaze-Duthier Canyon, 0.255 g cm^{-2}/yr; Rhone Delta, 0.15 g cm^{-2}/yr).

We found a significant peak in bamboo coral sclerites between 4 and 8 cm, and bases of coral colonies (see Fig. 2) at a depth greater than 8 to 10 cm. This sediment horizon corresponds to the period 1980–1985 when deep water trawling activity commenced in the area (see Fig. 4). We also found a decrease in abundance of pteropods which coincided with the massive damming of Ebro basin rivers from the 1950s to 1965, which was likely to have brought about a decrease in productivity. Populations of mesopelagic lanternfish (myctophids) showed significant fluctuations over time. Some species (*Lampanyctus crocodilus* and *Benthosema glaciale*) increased in abundance with positive North Atlantic Oscillation periods (NAO index, Fig. 3), which, in the western Mediterranean, means a lower rain regime. In parallel, the abundance of the lanternfish *Ceratoscopelus maderensis* increased with lower salinity in—characteristically salty—Levantine Intermediate Waters (LIW); a relationship already found for *C. maderensis* off Mauritania by Zelck and Klein (1995). The decrease in abundance of *C. maderensis* at MC4 could therefore be due to the increasing salinity recorded in the LIW since 1950. In general, there was a decrease in the abundance of myctophids over the last 100 years probably driven by the warming and increased salinity of the LIW. Given the crucial role of

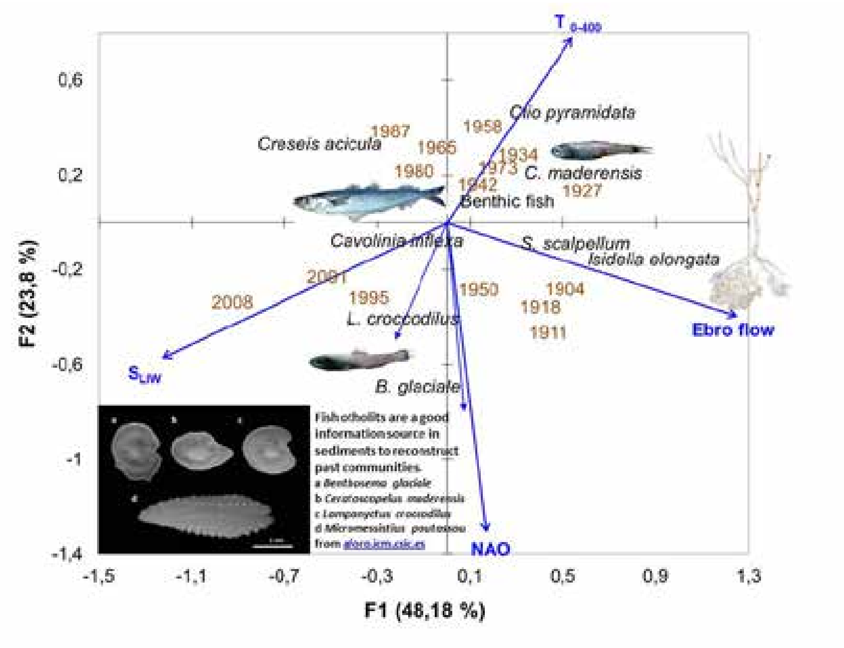


Figure 3. Simplified plot of the Canonical Correspondence Analysis (CCA) performed on the abundance of sub-fossil records of fauna in the MC4 sediment core (only main groups represented). CCA relates changes in the abundance of fauna with environmental variables, with arrow length being longer in the most important variables. $T_{0-400\,m}$ = mean temperature of the water column at 0–400 m depth; T_{LIW} = mean temperature of the Levantine Waters (LIW, at 200–400 m); S = salinity; NAO = North Atlantic Oscillation climate index. Numbers are the mid year of periods of ca. 14 yrs (as appear in Figure 2) deduced from radionuclide dating (Cartes *et al.*, 2017).

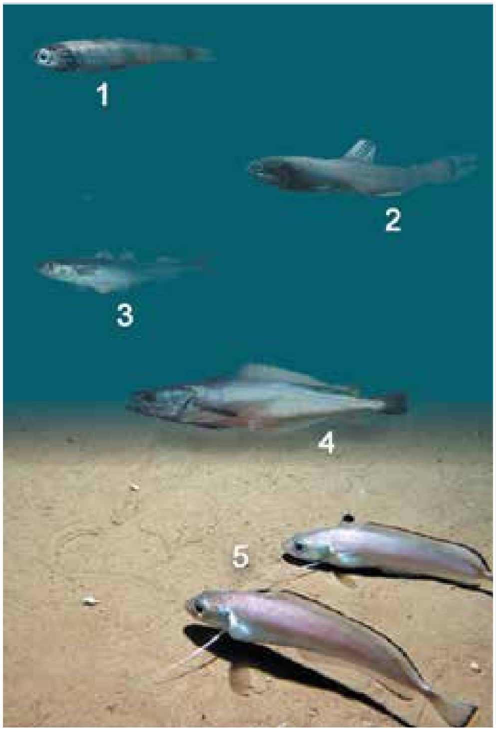
Figure 4. ROV and side-scan sonar (SSS) images serve to identify pristine (a) and impacted areas, e.g. by trawling activity (b, c). a) Field of *I. elongata* on muddy substrate (Balearic Basin at 450 m); b) SSS images showing trawler tracks off the Ebro river delta, 620 m depth; c) ROV image of a track made by a trawler door; d) Base of a large colony of *I. elongata*—remains of live colonies found on soft substrate after trawling. Images: Panoramic view of coral field © Oceana https://eu.oceana.org/es ; Trawler track © Dr. M. Demestre (ICM Barcelona, UE RESPONSE project).

lanternfish as an abundant prey species, such oscillations will have been likely to manifest at higher trophic levels.

Our results at MC4 correlated with long-term trends in living pteropods in zooplankton time series surveys (annual series from 1967–2003) in the north-western Mediterranean. Pteropods in sediment cores may therefore be useful indicators of past climatic variations. The abundance of the Creseidae group increased with higher temperatures in surface waters, whereas Cavoliniidae increased with salinity in intermediate waters (Fig. 3).

We can extrapolate the sediment accumulation rate model into sediments older than 100 years (deeper than 22 cm in the core). Off the Catalan coast Bas and Calderón (1989) related greater abundance of small blue whiting, *Micromesistius poutassou*, with maxima in solar activity. The peaks of *M. poutassou* must be related to periods of higher availability of their pelagic prey (krill, lanternfish), as we found at MC4 at 36–42 cm in the core, i.e. at 1840–1860. At this level the increase in abundance of blue whiting juveniles also coincided with peaks of lanternfish, their prey.

This attempt to reconstruct the biological community off the deep Ebro delta has helped us to identify different impacts on deep water systems. Among the human impacts we were able to correlate the onset of trawling activity during the 1980s with reductions in bamboo coral. Changes in the diversity of the zooplankton (as evidenced by the shells of pelagic pteropods) were probably caused by



Fish are one of the most useful target groups for the reconstruction of past marine communities. Fish species are distributed at different levels in the water column and near bottom over continental margins:
The midwater domain with lanternfish, *Ceratoscopelus maderensis* **(1)**, and *Lampanyctus corocodilus* **(2).** The bentho-pelagic level, with blue whiting, *Micromesistius poutassou* **(3)** and hake, *Merluccius merluccius* **(4)**
The benthic domain, with the greater forkbeard, *Phycis blennoides* **(5)**.
Midwater fish (lanternfish) accumulate the highest biomass in deep water trophic pyramids, so the most abundant sub-fossil remains (otoliths) found in sediments belong to these species.

Figure 5. Images 1-4 © Dr. D. Lloris. *In situ* image of *Phycis blennoides* © Dr. F. Sánchez (IEO Santander, https://www.ecomarg.com).

regulation of the Ebro river which would have resulted in a reduction in productivity offshore of the delta. We can also make inferences about natural changes: oscillations in lanternfish and other zooplankton suggest the influence of the long-term increase in salinity of Mediterranean LIW.

After the theoretical reconstruction, the next step should be the restoration of the ecosystem. The declaration of national marine parks or marine protected areas would allow the system to recover the biodiversity lost as a result of human activity. Our growing knowledge of the historical extent of key marine species enables us to define and refine MPA boundaries, and by comparing the distribution of species before and after the impacts we can evaluate the success of protection measures (for example: the bamboo coral is currently limited to depths below 1000 m that are free of trawling activity, see Fig. 1). Marine protected area boundaries are often decided by defined features such as seamounts or by special environments. In a more homogeneous sedimentary seabed setting, studies like ours could help to define the boundaries of protected areas based on historical distribution of species.

The 'ecosystem reconstruction' we present here is a novel study with little precedent in terms of similar work, and takes the next step from reconstruction to recommendations for restoration. This research has given a glimpse of the structure of pristine communities, and the opportunity to build targeted restoration strategies in important marine ecosystems, based on historical information.

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Glossary:

Foraminifera: tiny calcified animals with a global distribution, and whose tests are deposited in ocean sediments.
LIW: a characteristic salty and warm mid-water (200-400m depth) water mass of the Mediterranean, formed in the Levantine (easternmost) basin from where it spreads west, exiting through the Straits of Gibraltar.
Mesopelagic: migratory fauna living at intermediate depths of the sea water column.
Otolith: calcified structures of the inner ear of fish.
Pelagic: those organism living in the water column.
Pteropod: tiny, free-swimming gastropods.
Sclerite: minute calcite structures secreted throughout the coral providing structure and support.

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Further reading:

Cartes, J.E., Schirone, A., Barsanti, M., Delbono, I., Martínez-Aliaga, A., Lombarte, A. 2017. Recent reconstruction of deep-water macrofaunal communities recorded in Continental Margin sediments in the Balearic Basin. *Deep-Sea Research I*. 125, 52-64.

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The United Nations Decade of Ocean Science for Sustainable Development

As part of this bulletin focussed on the MBA's policy work, **Matt Frost** explains how our organization is engaging in the UN Decade of Ocean Science and how MBA members can get involved.

What is the UN Decade?

The United Nations proclaimed a 'Decade of Ocean Science for Sustainable Development' running from 2021 to 2030 in order to 'reverse the cycle of decline' in ocean health and mobilize the ocean science community. The Decade is seeking to achieve this by better mobilizing current capacity and the capabilities of marine science across the globe. Those two aspects are brought together in the phrase coined for the Decade: 'The science we need for the ocean we want'.

The Decade is being taken forward under the auspices of IOC-UNESCO with a major focus being on the implementation of Sustainable Development Goal 14 (Life Below Water). The overall mission is much broader, however, as it also contributes to various Sustainable Development Goals (SDGs) as part of the 2030 Agenda adopted by the UN in 2015.

Why is it important for the marine biological community to be involved?

There is a real sense of urgency in the marine science and policy community with regards to addressing the many issues in our oceans,